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ABSTRACT

Instructional research is reviewed where teaching failures have produced students who seem to be less able to use learning skills or had less access to knowledge in some domain than before they were taught. Three general types of "mathemathantic" (i.e. where instruction "kills" learning) effects are hypothesized, theoretical explanations for each effect are examined and representative studies in each area are described. The three types of effects described are where instruction serves to: (1) substitute learning procedures (e.g. novel learning strategies are hypothesized to interfere with the learning of higher general ability learners and inadequate learning strategies are provided to those with lower general ability); (2) impose less desirable motivational goals on learners (e.g. when teaching methods lead constructively motivated learners to believe that failure avoidance has replaced achievement directed goals and, conversely, when defensively motivated students believe that achievement directed goals have replaced the opportunity to avoid failure); and (3) substitute student control for system control over instructional method (e.g. by allowing lower cognitive load instructional methods to be chosen by high general ability, constructive students and/or by allowing higher cognitive load methods to be chosen by defensive students who have low general ability). A four-page bibliography and an outline of situations when mathemathantic effects are more probable are attached.
(Author/JAZ)

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WHEN TEACHING KILLS LEARNING:

TYPES OF MATHEMATHANTIC EFFECTS

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Abstract

Instructional research is reviewed where teaching failures have produced students who seem to be less able to use learning skills or had less access to knowledge in some domain than before they were taught. Three general types of "mathemathantic" (i.e. where instruction "kills" learning) effects are hypothesized, theoretical explanations for each effect are examined and representative studies in each area are described. The three types of effects described are where instruction serves to: 1) Substitute learning procedures (e.g. Novel learning strategies are hypothesized to interfere with the learning of higher general ability learners and inadequate learning strategies are provided to those with lower general ability); 2) Impose less desirable motivational goals on learners (e.g. when teaching methods lead constructively motivated learners to believe that failure avoidance has replaced achievement directed goals and, conversely, when defensively motivated students believe that achievement directed goals have replaced the opportunity to avoid failure); and 3) Substitute student control for system control over instructional method (e.g. by allowing lower cognitive load instructional methods to be chosen by high general ability, constructive students and/or by allowing higher cognitive load methods to be chosen by defensive students who have low general ability).

A central objective of educational research is to identify "mathemagenic" instructional methods (i.e. those that "give birth" to learning, Rothkopf, 1970). Researchers have generally come to expect that when instructional experiments fail, measured achievement or skill levels will remain at pre-experiment levels. Yet there has been increasing evidence for "mathemathantic" effects in instructional research (i.e. where instruction "kills" learning) since the construct was first suggested by Snow (1972). The thread that connects these diverse studies is their report that instructional treatments unintentionally produced a condition where students were less able to use learning skills or have less access to knowledge in some domain than before entering the experiment.

For example, in a math task involving the specification, intersection and separation of sets, Gagne & Bassler (1963) found it difficult to explain why an untreated control group significantly outperformed an experimental group on a nine week delayed retention test. The treated group had received training in applying intersection rules to a number of example problems. Sidel & Rothberg (1964) described a mathemathantic effect in one of the early computer programming studies. Experimental subjects, taught to state and write the rules for components of computer programs, performed significantly worse than control subjects who were only taught programming components. Similarly, in a study where various types of questions were inserted in an instructional text on Educational Psychology for undergraduates, Shavelson et al (1974) found that an untreated control group received significantly better quiz scores.

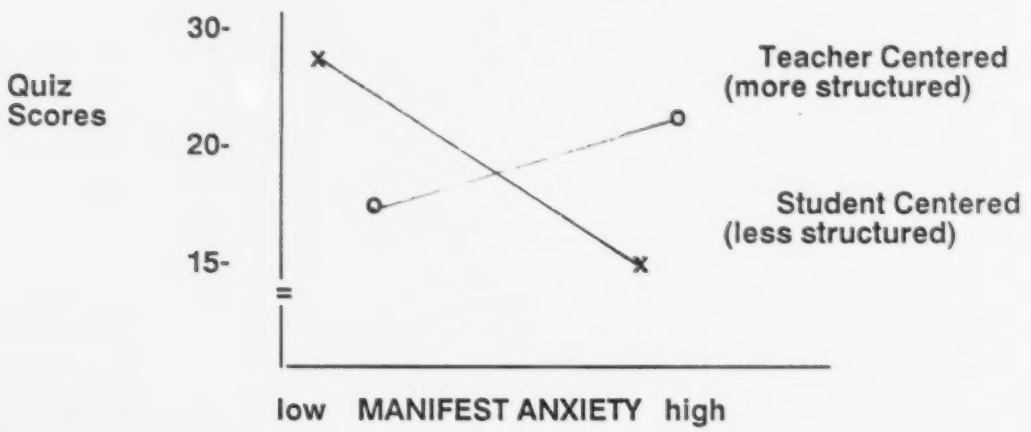
Operational Definition of Mathemathantic Studies. The Mathemathantic effect is operationally defined by one of four different instructional research outcomes: 1) a control group significantly outperforms a treated experimental group; 2) pre-test scores for an experimental group are significantly higher than post-test scores; 3) there are significant disordinal interactions between student's aptitudes and instructional treatments; and 4) where increasing amounts of some instructional treatment produces significantly negative correlations with learning outcomes. Except for the aptitude-treatment interaction (ATI) research characterized by condition three above, mathemathantic findings are seldom published and rarely discussed (Shavelson, Berliner, Loeding, Porteus & Stanton, 1974 and Lohman, 1986).

Previous Discussion of the Mathemathantic Effect. While a number of mathemathantic studies have appeared in the instructional research literature over the past 50 years, it was Snow (1972) who first suggested the construct to account for wide swings in performance by similar students who were exposed to different treatments in ATI studies. Interpreting these negative research results requires an analysis of the role that individual differences play in learning from instruction. What is mathemathantic for one aptitude level may be mathemagenic for another. In ATI research, the same instruction is presumed to support learning for students at one aptitude level while either producing neutral or negative effects for the other extreme of the same aptitude. In disordinal ATI's, all student's at one end of a relevant aptitude distribution have their learning depressed by at least one treatment. Higher aptitude scorers have their learning depressed by a treatment that

benefits those with low aptitudes, and vice versa. Given the current development of instructional theory, it is easier to account for increased than for depressed performance.

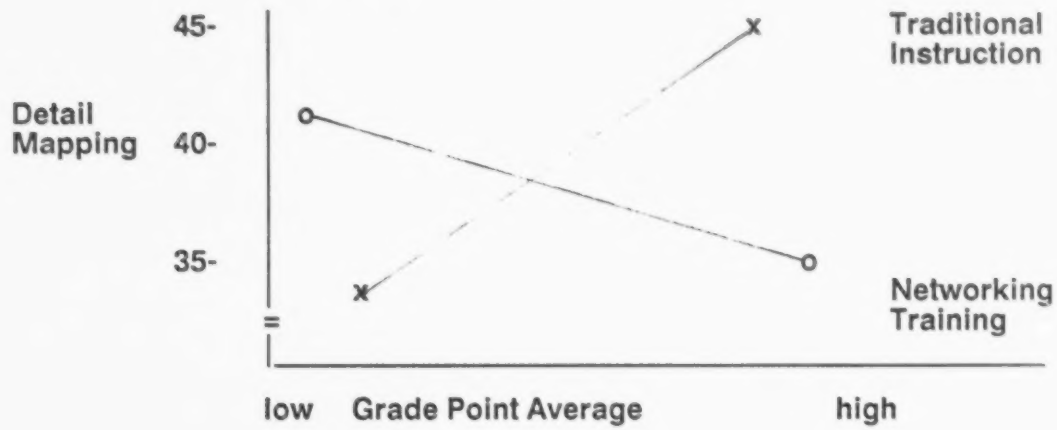
One interesting and often replicated example of a disordinal ATI was provided by Dowaliby & Schumer (1973). They contrasted "student centered" (i.e. unstructured, discovery oriented) and teacher centered (i.e. more directed and externally monitored) instruction for undergraduate psychology students who differed in manifest anxiety. On two examinations covering different course content over six weeks of instruction, ATI appeared (Figure 1). In both sets of data, higher anxiety students profited from the greater structure provided by the teacher-centered approach. Tobias (1985) reviews a number of similar studies and concludes that a more highly structured treatment reduces the demands on working memory imposed by the "worry" about failure that accompanies high levels of anxiety. Yet, few researchers have attempted to fully explicate the reasons for the depressed performance of low anxious students assigned to the more structured treatments in these studies.

Figure 1. ATI with anxiety predicting quiz scores under more and less structured treatments following Dowaliby & Schumer (1973)



In another disordinal ATI example, Dansereau et al (1979) taught the coding of text material into conceptual networks using either a mapping strategy (i.e., a procedure for locating and connecting similar conceptual categories) or a traditionally instructed control (expository description of the task requirements) for students with different grade point averages (GPA). The results (Figure 2) suggest a significant, disordinal ATI where lower GPA students profited from the strategy contained in the experimental treatment and were able to perform nearly at the level of higher GPA students. Presumably, some features of the networking treatment compensated for the skill deficits represented by lower GPA scores. However, here also it was difficult to explain the very depressed performance of the high GPA scorers except to suspect that the networking treatment had somehow "interfered" with their learning.

Figure 2. ATI with GPA predicting detail mapping for treated and untreated groups following Danserau et al, 1979.



Clark (1982) speculates that a pattern of significant negative outcomes in instructional research have been ignored because of the practical goals of educational research. The search for robust instructional methods have led us away from attempts to explain treatments which depress learning when evidence of a successful alternative exists. Yet, it is likely that an exploration of the cause of mathemathantic events will increase our eventual knowledge about learning from instruction.

Purpose. The purpose of this paper is to analyze and classify mathemathantic studies. The analysis will be conducted in order to provide tentative descriptions of the cognitive processes underlying the different types (and related subtypes) of effects. The topology will be based on an appraisal of the cognitive functions served by the diverse instructional methods employed in the studies reviewed. The approach taken in this analysis makes the assumption that a critical function of all instructional methods is to externally support cognitive processing (Clark & Voogel, 1985). It will emerge from the analysis that all mathemathantic effects appear to have one factor in common -- when instruction substitutes inadequate or disliked cognitive processes, goals or learner control for those that are demonstrably more adequate or better liked, learning will suffer. The evidence reviewed for this discussion indicates that mathemathantic substitution tends to operate in three areas: 1) Learning Procedure Substitution where interfering learning strategies are imposed on high aptitude subjects or inadequate learning strategies are forced on low aptitude students; 2) Motivational Substitution where subjects are forced into learning goals that they dislike; and 3) Student Control Substitution where instructional systems permit student control over the choice between alternative instructional methods for learning the same subject matter and those students at the extreme ends of ability distributions seem often to make inappropriate choices for themselves.

I. Learning Strategy Substitution

Whenever an instructional treatment encourages students to replace an existing, effective learning strategy with a dissimilar alternative, learning is depressed. Strategy substitution tends to take two forms: 1) Novel Strategy Substitution seems to primarily affect higher aptitude students by replacing more automatic and effective strategies with less familiar strategies. Different types of novel learning strategy substitutions seem to interact with different components of general ability; and, 2) Inadequate Strategies affect lower aptitude students by providing them with unsuccessful and/or incomplete learning procedures.

Novel Strategy Substitution. When instruction imposes an unfamiliar learning strategy on higher aptitude students their learning is depressed as they attempt to employ the new approach. These novel learning strategies interfere with the skill repertories of higher ability students. Nevertheless, the same strategies that are mathemathantic for higher aptitude learners, often benefit low aptitude students who simply lack an effective approach. Snow (1980) has argued that aptitude for learning is best characterized by the efficient use of effective cognitive skill assembly and control processes. A number of specific cognitive correlates of novel strategy substitution have been described recently by Lohman (1986). He notes that various component's of higher aptitude processes may be interfered with by different types of strategy substitution. It is important to note that there may be two main types of replacement strategies that interfere with the learning of high aptitude scorers -- either procedural or declarative learning strategies. This distinction is compatible with similar categories used to identify the procedural and declarative differences between learning tasks commonly employed by cognitive psychologists (e.g. Rumelhart & Norman, 1981). Procedures are specific sequences of behavior that have a goal (e.g. steps in a procedure for adding three digit numbers). Declarative strategies are thought to be involved in the connecting of knowledge between domains (Corno & Mandinach, 1983). Here, conceptual strategies such as analogy and metaphor are used to create new knowledge to solve novel problems (e.g. the math teachers use of the "slice of pie" analogy to introduce addition and subtraction of fractions).

The substitution of either declarative or procedural learning strategies may produce dissimilar mathemathantic effects for students who possess different levels of crystallized or fluid ability (Snow, 1980). Fluid ability depicts flexible adaptation to novel learning tasks and is represented by scores on the Progressive Matrices (Raven, 1962) scale. Crystallized ability represents a learner's skill at more familiar, school-based tasks. One way to illustrate the possible interactions between learning strategies embedded in instructional methods and learner aptitude would be in a 2 x 2 table similar to the one depicted in Table 1.

EXAMPLES OF MATHEMATHANTIC LEARNING STRATEGY TREATMENTS

APTITUDE TYPES		Declarative	Procedural
	High Fluid Ability	Holyoak (1984) Analogies	Skanes (1974) Direct practice
	High Crystallized Ability	Snow (1980) Debugging Help	Danserau et al (1979) Networking

TABLE 1. Studies representing four types of mathemathantic substitutions that result when either declarative or procedural learning strategies are provided to students with high levels of crystallized or fluid aptitude.

Declarative Substitutions for High Fluid Aptitudes. Research on novel substitution of declarative learning strategies for high fluid learners is meager. There is some evidence that when declarative instructional methods such as analogies are imposed on high fluid scorers, it depresses their performance (Clark & Voogel, 1986; Royer, 1979). Holyoak (1984) noted that only high fluid ability learners seem to spontaneously employ analogies during learning and problem solving. Sternberg (1985) has argued that the ability to use analogies successfully characterizes fluid skill. Clark & Voogel (1986) maintain that analogies serve to facilitate "far transfer" (Royer, 1979) which is the critical skill represented by fluid ability. Presumably, when instructional methods impose analogies they conflict with the more successful elaborations that are spontaneously generated by high fluid learners. Students with high crystallized but low fluid scores on the other hand, might be expected to benefit from provided analogies. This may be part of the reason why analogical treatments sometimes aid learning for high ability students and sometimes have mathemathantic effects (e.g. Gick & Holyoak, 1983; DiVesta & Peverly, 1984; Lohman, 1986).

Procedural Substitutions for High Fluid aptitudes. The substitution of a novel procedure for fluid learners often involves the imposition of productions that are thought to underlie transfer of learning. Sternberg (1985) describes typical procedures employed by successful analogy users and solvers. Using an analogy requires the mastery of procedural steps such as mapping the similarities in both the source and target domain and excluding negative transfer elements. When these procedures are taught to high fluid learners, they compete with their existing idiosyncratic procedures that have

been serving to facilitate the use of analogies. The result is presumably that the new procedure is not learned effectively and the "old" procedure is weakened (Anderson, 1983). For example, Skanes et al (1974) sought to teach children to solve complex letter series problems at a "high transfer" level by using either direct practice (a procedure for generalizing rules across cases) or an indirect practice condition that simply provided rules and offered opportunities to solve problems. The high transfer, direct practice treatment interfered with students who's Progressive Matrices (Raven, 1962) scores were above 133. Since the Raven's measure is accepted as one of the general indicators of fluid skill, one might assume that the higher fluid scoring subjects experienced interference when they attempted to use the transfer procedure employed in his direct practice treatment.

Declarative Substitutions for High Crystallized Aptitudes. Novel strategy substitution also produces mathemathantic effects in studies where treatments provide declarative substitution for high crystallized subjects. Crystallized aptitude tends to be represented by expertise in subject matter domains. Here, experience in identifying and employing more declarative elaborations of facts, concepts and principles permit domain specific learning and problem solving to occur. This is probably the explanation for the strongly negative correlations and regression slopes that resulted when measures of crystallized ability were used to predict learning scores in the large-scale study reported by Snow (1980). Computer-based training was given to college students to teach a large number of specific computer programming problems. The instructional program included conceptual models for "debugging" programs and elaborative "help" for other learning problems that reduced the learning of those with higher crystallized aptitude.

Procedural Substitutions for High Crystallized Aptitudes. Anderson (1985) has carefully described the consequences of attempting to replace steps or entire sequences of automatized learning procedures. This type of procedural substitution operates like the one described above for high fluid aptitude scorers. The difference is that the procedures embedded in these treatments seek to replace the school and/or experience-based, content-rich procedures that characterize crystallized ability (Snow, 1980). Here, instructional methods force students into an unfamiliar procedure for solving problems in familiar domains. This was probably the phenomenon that accounts for the data reported by Dansereau and his colleagues (Dansereau, McDonald, Collins, Garland & Holley, 1979). A "networking" treatment presented a procedural method to college subjects for a hierarchical mapping technique intended to facilitate the transformation of text into "node networks" (concept-link relationships) to facilitate prose processing. A control group was allowed to use their existing strategies for prose processing. Note in Figure 2 that the imposed networking procedure actually resulted in significantly lower achievement scores by high GPA students. Here, grade point is presumed to be representative of crystallized aptitude. The concern with this type of treatment stems from Anderson's (1983) claim that procedural interference may lead to long-term negative effects.

The mathemathantic effects described thus far affect higher aptitude scorers. Since lower aptitude learners do not have composed procedures for attacking learning tasks, when other things are equal, they tend to be helped

by the strategies that inhibit the learning of those with higher aptitude. Yet, there are a class of mathemathantic effects that seem to be specific to those with low levels of crystallized and fluid skill.

Inadequate Procedural Strategy Substitution. Rohwer (1979), in a discussion of "how the smart get smarter" complained that teachers often attempt to provide inadequate learning strategies for slow or novice learners. These inadequate procedures are sometimes derived from analyses of the learning strategies apparently used by skilled performers at a task. He noted, for example, that mathematics teachers discourage the concrete "finger counting" that slower math learners use while performing arithmetic operations. Mathematics teachers tend to encourage their own more "abstract" learning strategies that seem not to help the lower aptitude or younger subjects. When expert task analyses are used to construct procedures to be taught to novices, they are often "incomplete" because they contain automatized "chunks" of procedures as single steps (Anderson, 1983). Lower aptitude learners are characterized by a lack of effective learning strategies. In many cases these learners have never acquired a workable approach to mastering certain learning or problem solving tasks. So, mathemathantic instructional methods "substitute" an unworkable or irrelevant strategy for no strategy or for one that is incomplete. Studies by Case (1978) that describe the procedural defects experienced by children in their performance of developmental tasks such as conservation of liquids, support this description of mathemathantic effects.

Inadequate Procedures in Computer Based Instruction Studies. Evidence from many short-term instructional studies suggest that "...situations of optimum learning require a great deal of preparation. If we do experiments in learning with only superficial preparation -- instructions, "training", etc., of short duration -- then the rare things get swamped by statistical noise." (p. 6, Hawkins, 1966, in Cronbach & Snow, 1977 p. 130). The reason for this noise seems to be that students are also swamped. Research subjects and classroom students seem to require "tuning", i.e. an opportunity to develop procedures that permit them to utilize new teaching methods and media. When novel and complex instructional media are introduced to students without sufficient tuning, learning seems often to be depressed. For example, Clark (1985) describes a number of computer-based instruction studies where lower general ability subjects were apparently not given sufficient procedural support in the use of the computer medium. As a consequence, they were unable to take advantage of the lower cognitive load instructional programs that the computer offered. Clark (1985) cautioned that this weak preparation element in computer-based instruction studies has confounded the results of those studies. Because inadequate procedural preparation was offered in a number of key studies, reviewers in that area have sometimes concluded that computers provide more learning support for higher ability students (e.g. Kulik, Kulik & Cohen, 1980).

Inadequate Declarative Strategy Substitution. There are also weaker declarative strategies that interfere with learning. Samuels (1967) taught word recognition using pictures and a no-picture control where the experimenter merely repeated the word that was presented. For low word-

recognition pretest scorers, the no-picture controls outperformed the picture conditions. The pictures may have been distracting and irrelevant for low aptitude subjects. In a study by Sullivan, Okada and Nidermeyer (1971) slow readers with an inadequate letter combination (whole word) treatment performed significantly below their pretest level on word elements and new word recognition. And, an investigation of note taking on memory for lecture information for undergraduate students (Peters, 1972) reported that instructions to take notes significantly reduced the test performance of poor listeners. In addition, poor listeners in the note-taking condition who were observed not to be actively taking notes performed at about the same rate as their untreated control cohorts. One might speculate that note-taking was irrelevant to the measured performance.

Inadequate Substitutions for Students With Different Aptitudes. It is likely that a weak strategy substitution influences subjects who are low on crystallized aptitude differently than those low on fluid aptitude. The study by Skanes et al (1974) strongly suggests that the aptitude and task differentiation is as necessary to fully understand weak substitution as it is to explain novel strategy substitution. Skanes and colleagues found that low crystallized middle school students who were pretested on Thurstone type letter and number series problems performed significantly worse than non-pretested students. However, higher crystallized scorers and all levels of fluid aptitude students performed better with pretests. The experimenters concluded that pretests served as an inadequate and procedural "practice session" for low crystallized students and imposed on a "muddled background" of skill and served to "consolidate confusion". Rumelhart & Norman's (1981) discussion of the use of inadequate or limited analogies in learning are also strongly suggestive of mathemathantic effects for low fluid scorers when they perform more declarative tasks. They explore evidence that analogies commonly used by teachers may facilitate short term learning goals at the expense of longer term goals. For example, the "slice of pie" analogy helps low fluid learners "decontextualize" declarative understandings of fractions. The analogy apparently helps low fluid ability students transfer operations from slicing pies or cakes to the addition and subtraction of fractions. However, the same declarative learning strategy seems to inhibit the learning of the multiplication and division of fractions through negative transfer (Rumelhart & Norman, 1981; Voogel, 1987).

II. Motivational Goal Substitution

Learning strategy substitution does not explain another large group of studies where mathemathantic effects are often found. In the learning strategy substitution studies, ability differences influenced mathemathantic outcomes. In the next series of studies to be discussed, general ability differences were controlled and learning differences remained. These learning differences appear to be due to motivational variables. For example, Domino (1968, 1971, 1974) varied the amount of external direction and control imposed on students who differed in their scores on the California Psychological Inventory subscales for achievement through independence (Ai) or Achievement through Conformity (Ac). In his 1968 study, a 2 x 2 design

varied reinforcement for either conformity or independence for those with high Ai or Ac scores. When, for example, high Ai students were reinforced for conforming behavior, their learning suffered compared to high Ai's who were reinforced for independent behavior. In his 1971 study, college psychology students with extreme Ai or Ac scores were assigned to instructors who either required high levels of conformity or independence. Scores on a variety of learning measures indicated that while main effects for achievement were generally nonsignificant, disordinal interactions between aptitude and treatments were highly significant. Learning and enjoyment were both depressed when students were assigned to teachers whose style was antagonistic to their preferences. In his 1974 study Domino used Guilford's tests for divergent and convergent thinking and compared a less directive with a more guided tutorial treatment in a college poetry course. There were no main effects but a predicted, significant disordinal interaction was found. Divergent thinkers achieved more with the traditional open course and convergent thinkers benefited most from the structure imposed by the tutorial treatment.

Constructive and Defensive Motivation. The instructional research literature provides many similar examples of studies where varying the amount of structure and direction imposed on students produces disordinal interactions with personality variables in a complex that Cronbach & Snow (1977) called "constructive and defensive motivation". This complex includes achievement through conformity (Ac) and independence (Ai), measures of trait anxiety (Ax) and need for achievement (nAch) and to avoid failure. Extreme scores on this complex have been interpreted as expressing strong goal preferences either to avoid failure or to achieve success. The more "defensive" (i.e. anxious, conforming and failure avoiding) student seems to work with the belief that failure is more controllable with higher levels of structure and direction during instruction. Conforming students seem not to invest sufficient effort in unstructured, more independent settings and therefore achieve less. The more "constructive" (relaxed, independent and achievement oriented) student places high value in success and seems to believe that greater freedom during learning will produce more success. When faced with instructional methods that impose relatively high amounts of external learning control (e.g. methods that contain more structure, external monitoring, specific directions and frequent progress testing) the constructive student reduces the amount of effort they invest in learning. For example, when constructive students were assigned to organized, sequenced, directive instruction they reduced their effort and achieve less in a study by Clodfelter (1969). When he gave frequent quizzes to high Ai physics students, they achieved less than an equivalent group who received no quiz and no feedback. Defensive students (high Ac) in his study, achieved more with frequent quizzes than in the no quiz condition. There were no significant differences in GPA between Ai and Ac students.

Replacing Failure Avoiding or Success Directed Motivation Goals. One plausible interpretation of this literature may be found in cognitive motivation theory (Mook, 1986). Students seem to believe that different types of instructional methods support different learning goals. The more structure, direction and external monitoring imposed by the method, the more the

instruction is believed to support the avoiding of failure. More independent, discovery oriented and unstructured methods are presumed to support the achievement of success. The evidence from existing studies gives some support to the notion that beliefs seem to underlie motivational mathemathantic effects.

A number of separate studies that provide supporting evidence for this motivational effect (See Table 2) were described by Cronbach & Snow (1977). More recent discussions of cognitive theories of motivation (e.g. Schunk, 1984; McClelland, 1985; Morgan, 1984; and Salomon, 1984, Mook, 1986) portray motivation as the consequence of a rational belief system. Most cognitive theories rest on the assumption that motivation stems from beliefs about one's self and the learning task. Bandura (1982) and McClelland (1985), tend to agree on the variables that influence decisions to invest effort in learning. Bandura's theory implies that all human beings implicitly ask themselves two questions before investing effort, "What is required of me in this task?" and "Do I have what it takes to achieve my goals?". McClelland (1985) adds "value" as a different yet significant consideration. He suggests that students are generally concerned about whether any given segment of instruction has value or incentive for them. Salomon (1984) characterizes Bandura's task question as the "perceived demand characteristics" (PDC) in learning and the skill question as "perceived self efficacy" (PSE). He offers evidence that the relationship between both PDC, PSE and effort is an inverted U (See Figure 3). With either exceptionally low or high amounts of either PDC or PSE, very little effort will be expended by learners. McClelland argues that the value one identifies in a task determines whether one will choose to become engaged.

Figure 3. Expected relationship between perceived self efficacy (PSE), perceived demand characteristics (PDC) of tasks and amount of effort expended during learning (Following Salomon, 1984).

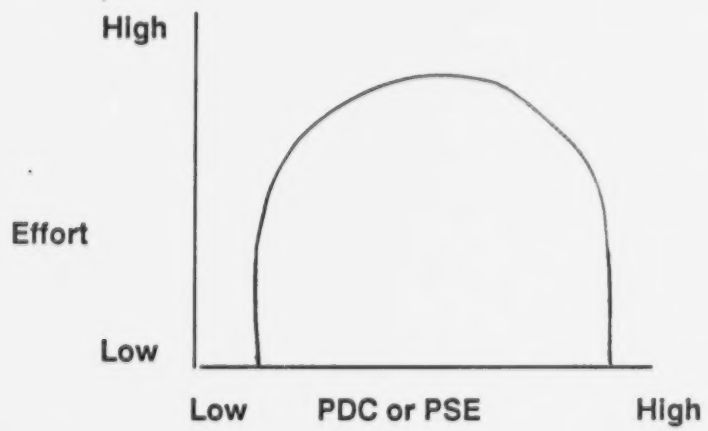


Table 2

MOTIVATIONAL STUDIES DEMONSTRATING MATHEMATHANTIC EFFECTS

Study Author(s)	Motivational Aptitude	Treatment Type
Parent et al, 1975	Locus of Control	Teacher Discipline
Karabenick & Youssef, 1968	nAch + Ax	Easy vs Difficult Paired Associates
Snow, 1963	Ascendence Assertiveness	Filmed vs live Physics Demonstrations
Clodfelter, 1969	Ai, Ac	Physics Quizzes and feedback on progress
Hiller, 1972	Ax and Self-confidence	Inserted questions in introductory psychology
O'Connor, Atkinson & Horner, 1966	nAch + Ax	Ability Grouping of Boys
Gardner, 1974	nAch	Competitive Teachers
Admion & Flanders, 1961	Dependency	Direct vs Indirect Teacher Style
McKeachie, 1963	nAch + Ax	Structured Environments
Peterson, Janicki & Swing, 1980	Ai + Ac	Teacher guided inquiry vs Lecture/recitation

nAch = Need for Achievement
Ai = Achievement through Independence
Ac = Achievement through Conformity
Ax = Trait Anxiety

It may be that constructive learners value the independent pursuit of success. When instructional methods allow them freedom to employ their own skills in their own way they become more engaged in a learning task. In general, their perceived self-efficacy may be moderately high and moderate self efficacy may often be combined with task demands that are moderately difficult. Unstructured learning tasks are considered to produce a "higher

cognitive load" (Snow, 1980) for these students. The combination of moderate task load and moderate self-efficacy is the point where Salomon (1984) predicts the greatest effort expenditure. Yet, when the increased structure and direction typical of low load treatments cues them to a disliked "failure avoiding" goal a mathemathantic spiral may begin where: 1)the structured treatment lowers their perception of the demands of the task and changes their view of its goal; 2) their self efficacy judgments grow to very high levels; and 3) their motivation then may sink below the level necessary to produce the effort necessary to learn. A similar scenario could be imagined for defensive students. They may have lower self-efficacy (which leads them to value the avoiding of failure). They also perceive learning tasks as more difficult and demanding than do more constructive learners. When more unstructured, discovery oriented methods are employed, defensive may sense the increased probability of failure. This begins their mathemathantic spiral where: 1) the unstructured treatment increases their perception of the difficulty of the learning task and changes their view of its goal; 2) their self efficacy judgments sink to even lower levels; and 3) their motivation then falls to the point where they are unwilling to invest the effort needed to learn.

III. Substituting Student Control for System Control of Method

The final mathemathantic effect to be discussed can be understood as a special case of a higher order interaction of types I (learning strategy substitution) and II (learning goal substitution) described above. It appears to occur when students with either higher or lower general ability are allowed to choose between instructional methods differing in amount of structure and direction but presenting the same curriculum content. So, for example, college students may be offered the option of enrolling in a course presented either by a highly directive, structured, computer-based instructional program that provides constant feedback on progress or they might select a version that is more traditional and less structured (i.e. lecture with reading and a midterm and final examinations). Clark (1982) reviews ATI studies where students either choose or were assigned to treatments that differed in structure and where both learning and "enjoyment of instructional method" measures were collected (Table 3). He found that there was a pattern of "antagonistic" outcomes in these studies that fit the definition of mathemathantic effects. In most of the studies selected for review, students with either high or low general ability scores reported liking the instructional methods from which they learned the least. Lower cognitive load methods were preferred more by higher general ability students who liked them more but learned less from them than from higher load methods. Conversely, the less structured and more demanding higher load methods were liked better by lower general ability students who learned much less from them than from the lower load methods.

Table 3

ATI Studies Where Students Enjoyed The Less Effective Treatment (Following Clark, 1982)

Study	Treatment	Mathemathantic Effect
Wispe (1951)	Permissive(H) Directive(L)	Low Ability liked permissive but learned best with directive.
Maier & Jacobs (1964)	TV(L), PI or TV + PI(H)	Low ability liked the higher load TV but learned best from TV + PI
Maier & Jacobs (1966)	Scrambled PI (H) Logical PI(L)	Low ability liked the scrambled but learned best from the logical.
Morris & Kimbrell (1972)	Lecture(L) Keller (H)	Highs liked Keller but learned more from Lecture. Lows liked lecture but learned more from Keller Plan.
Peterson (1977)	Low & High Structure	Highs liked low structure but learned more from high structure. Lows liked low structure but learned from high.
Peterson (1979)	Low & High Structure	Highs liked low structure but learned more from high. Lows liked low structure but learned from high.
Peterson & Janicki(1979)	Small Group(H) Large Group(L)	Lows liked high load small group but learned more from low load large group.

PI = Programmed Instruction
L = Low Cognitive Load Treatment
H = High Cognitive Load Treatment

Clark (1982) and Salomon (1984) have explained this mathemathantic effect using motivation theory. It appears that when both high and low ability students are allowed to choose between instructional methods, they make estimates of the "demands" of the alternatives. Clark's (1982) review it was the low ability students who most often chose higher cognitive load methods but, as would be expected, learned more from lower cognitive load methods. Why do lower ability subjects choose higher load methods? Clark suggested that lower ability students tend to choose the more difficult alternative because these instructional methods permit more freedom and anonymity during learning. The methods also allow a great deal of freedom

for students to schedule and direct their own time and effort on learning tasks. The openness of the higher load options enables students to invest less effort and to fail in private. Clark's explanation for the tendency of higher ability students to choose lower load methods was also motivational. He thought that high aptitude learners expected the more structured and directive methods to provide a more direct and less difficult route to higher test scores. With the benefit of recent developments in motivation theory, we can expand on Clark's explanation. It is likely that the antagonism effects depicted in Figure 3 are the result of an interaction of ability and motivational style. From the studies reviewed in the previous section we might expect that the higher general ability students in Clark's (1982) review who chose lower load methods were more conforming. Lower general ability students may have been acting more independently. The only direct evidence in these studies comes from Peterson (1977, 1979) who collected Ai and Ac scores on her subjects. As expected, more conforming students liked the lower load methods and more independent students liked the higher load methods. While there is no direct evidence, it is plausible to assume that higher general ability students who are also conforming would like lower load methods but learn more from the higher load. Perhaps the conforming student's attraction to these methods contributes more variance to the measure of attraction than that of the independent students. Similarly, Peterson's independent students at all ability levels, expressed strong preferences for higher load treatments. This preference would be expected to produce a mathemathantic effect for lower general ability subjects who are allowed to choose methods.

Summary and Conclusion

In the foregoing discussion, instructional research was reviewed where teaching failures have produced students who seem to be less able to use learning skills or had less access to knowledge in some domain than before they were taught. Three general types of "mathemathantic" (i.e. where instruction "kills" learning) effects were hypothesized, theoretical explanations for each effect are examined and representative studies in each area were described. The three types of effects depicted are those where instruction serves to: 1) Substitute learning procedures (e.g. Novel learning strategies are hypothesized to interfere with the learning of higher general ability learners and inadequate learning strategies are provided to those with lower general ability); 2) Impose less desirable motivational goals on learners (e.g. when teaching methods lead constructively motivated learners to believe that failure avoidance has replaced achievement directed goals and, conversely, when defensively motivated students believe that achievement directed goals have replaced the opportunity to avoid failure); and 3) Substitute student control for system control over instructional method (e.g. by allowing lower cognitive load instructional methods to be chosen by high general ability, constructive students and/or by allowing higher cognitive load methods to be chosen by defensive students who have low general ability).

Generally, there appears to be compelling evidence in instructional

research for Snow's (1972) construct of "mathemathantic" effects. Most important is that a psychological explanation of the types of this negative outcome of instructgion requires an analysis of the individual differences of students. While many different aptitudes may produce harmful interactions with treatments, the studies surveyed in this report focused on measures of crystallized and fluid skill (Snow, 1980), and constructive and defensive motivation (Cronbach & Snow, 1977). Under some treatment conditions it might be expected however, that measures of prior knowledge, personality and style would also result in mathemathantic effects.

Treatment conditions that appear to combine with aptitude to often produce these effects are those where 1) learning strategies are embedded in an instructional presentation (they serve as interfering substitutions for high aptitude learners and sometimes as inadequate learning procedures for those with low aptitude); 2) the amount of structure and direction provided the student is either very high or very low (these conditions seem to suggest different motivational goals to students) and 3) the choice of more or less structured methods is offered (the wrong choice seems to be made by students who are either very high or low on general ability measures)

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MATHEMATHANTIC EFFECTS ARE MORE PROBABLE WHEN INSTRUCTION SERVES TO:

1) SUBSTITUTE LEARNING PROCEDURES, such as when...

Novel Learning Strategies Replace Automatic Productions. Low load methods substitute weak procedures for the more automatic and successful productions that characterize High G learners. The result is that the weak procedure interferes with and weakens the successful procedure and produces lower learning scores than would be achieved with no treatment.

Inadequate Strategies are Provided. Low load methods may also substitute faulty procedures for the incomplete productions that characterize Low G learners. The result is an incorrect procedure that is becoming automatic through practice. While the procedure may be learned, the task(s) it is designed to serve will not be learned because the learning procedure is faulty. e.g analogy in fractions, "learning to learn" skills.

2) SUBSTITUTE MOTIVATIONAL GOALS, such as when...

Failure Avoidance Replaces Achievement Directed Goals. Low load methods are typically perceived as supporting the need to avoid failure. High Ai students are described as valuing success and the conflict elicited by their preferred goals and those implicit in the instructional method lead them into avoidance behaviors which reduces the amount of effort they invest and, in turn, their learning.

Achievement Directed Replaces Failure Avoiding Goals. High load methods are typically perceived as supporting the need for success and achievement. This places high Ac students in conflict with their need to avoid failure. This conflict leads to avoidance behavior.

3) SUBSTITUTE STUDENT CONTROL FOR SYSTEM CONTROL OF METHOD,

This mathemathantic effect is the higher order interaction between the method, ability and motivational types described above. Two varieties of this effect are evident in instructional research:

Higher Load Methods Chosen by High G Students. When high G students who are also high Ac are allowed to choose between higher and lower load methods, they will typically choose on the basis of their motivational goal (to avoid failure through conformity) and select lower load methods. While these methods are liked and the student is both engaged and willing to expend effort, they do not learn as much as they would from high load methods because of the effect described in #1 above.

Lower Load Methods Chosen by Low G Students. When low G students who are also high Ai are allowed to choose between methods that place more and less cognitive load on them, they will typically choose the higher load method. This choice satisfies their values but leads to less learning because they require the compensatory procedures and structure of the lower load method.